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Analysis and visualisation of stakeholder relationship in Offsite construction: Social Network Analysis approach

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Abstract. While Off-site construction has emerged recently, its benefits have long been proved worldwide. Many hold that Off-site construction is re-structuring the industry, its supply chain and setting supplementary standards. Although stakeholder theory is prevailing in project management research, there is still a lack of in-depth research upon patterns of interrelationship and communication among Off-site construction stakeholders. Given that in Off-site construction project-based organisations are multi-level structures, stakeholders interact with each other not only within-level but also cross-level. To facilitate the adoption and diffusion of Off-site construction, there is a need to address patterns and find out the optimal mechanism for promoting inter-collaboration. Social Network Analysis is presented as a holistic approach to meet that need in a more quantitative and unambiguous way. Based on a critique of Off-site construction literature and Social Network Analysis theory, a conceptual framework is also proposed for Off-site construction stakeholder research themes and corresponding methodology. The aim of this paper is to contribute to a sound theoretical foundation for the development of a social network model and the understanding of the complex of connection and relationship among Off-site construction stakeholders.

1 Introduction

Off-site construction refers to manufacture of building components or parts at a different location from where they are built permanently. However, it is not a novel method. OSC products have been launched since the beginning of 20th century, for instance, developers in the USA had started selling 'kit homes' in the early 1900s and the governments of Europe switched to offsite housing construction all sides of the Iron Curtain after the 2nd World War to tackle housing shortage [1]. Offsite manufacturing use is currently emerging worldwide because of changed consumer attitudes, the implementation of government aid programmes and the popularity of major case studies [2] and the rise of building information modelling, advanced information, automated and robotic technologies [3]. In international research, the advantages of this method have been widely acknowledged, such as shortened schedule, remarkable buildability and increased on-site safety.

The Australian economy keeps gaining momentum and recent surveys show increasing optimism across the construction industry [4]. Notwithstanding, multiple criticisms have been made against the performance of that sector. Australian housing prices, for instance, continue being evaluated “severely

unaffordable" in the world [5]. Townsend [6] exposed that Australian cities are still among the top most expensive places for construction projects in the world. At the same time, the level of conformity to environmental regulations have been low [7]. Average completion times for houses/townhouses remained fairly steady whilst ones for flats, units or apartments have increased over the past decade [8]. Off-site construction is deemed a pragmatic solution to these chronic problems in the coming decade. The Australian industry players are now inspired by the feats of OSC and its associated activities by developing network such as PrefabAUS at the end of 2013, and by launching the Buildoffsite from UK to Australia in May 2014 [9].

According to Jin et al. [10], in past decade, it was witnessed that the general trend of publications upon OSC has been increasing and is expected to continue growing in the next few years. It is seen that Australia, China and UK dominate the pool of recent researches in OSC. Most of these are at introductory level or fairly in-depth but not much discussed about human relation facets of OSM projects [11]. Hu et al. [12] found out that the topic of stakeholder relationship only accounts for 14/168 (i.e. 8.3%) in terms of frequency in OSC stakeholder literature. Ji et al. [13] most notably adopts SNA to explore the stakeholder relationships during Chinese construction industrialization. Having said that, Ji et al. [13] predefining stakeholders might omit certain ones, thereby oversimplifying the network and its indices. Besides, that study overfocused on mathematical structure of networks so neglecting the sociological aspects and its implications for the whole industry. Not to mention, the authors [13] restricting the relation among stakeholders to "communication, reliability, trust, and commitment" might mis-decipher the interrelationships that inherently include but not limited to payments [14], incentives to perform [15], contractual relationships [16, 17], information exchange [14], risk transfer [18], knowledge sharing [19].

2 OSC stakeholders and the inherent characteristics

2.1 OSC and stakeholder theory

The purpose of OSC is to move some of construction activities from building site into a controlled factory environment [20]. Many believe that by transposing these construction activities to manufacturing bases, time and cost are likely to be certain, productivity and quality might be enhanced, waste generation and dependency towards skilled workforce might be reduced [9, 21, 22]. OSC activities are experiencing another upsurge in recent years owing to the growth of BIM and other digital innovations [23]. The publication of off-site technology in mature industries, like the United States and the United Kingdom, is considerable. Meanwhile, there is very little knowledge of the status of OSC within the construction industry in Australia [24].

Many believe that a construction project's on-going performance and successful completion are greatly impacted by both the perceptions and interactions of its stakeholders. Inefficient stakeholder management may sow the seeds of project time and cost overruns [25]. Stakeholder theory is "an important trend in project management research." [26] However, some authors [25, 27-30] addressed multiple weaknesses of stakeholder management research as follows:

1. few studies identify alteration in stakeholders' influence and relationship over the course of project implementation
2. small emphasis on the effect of the stakeholder relation networks on the project performance.
3. the existing techniques mostly use a qualitative perception of stakeholders' importance rather than a quantitative analysis
4. little research manifests the effect of the whole network of relationships

Notably, in recent studies [31-34], Professor Kerry London and her co-authors were considering collaboration and supply chains in OSM using actor-network theory, Systems Dynamics, Causal Loop Diagrams, etc. Other researchers like Gan et. al, Li et al. [35, 36] also used similar methods and approaches to undertake studies upon matters revolving on stakeholders. Not only OSC stakeholders are under-researched compared with stakeholders in on-site traditional construction. There is also an urgency for intensive study of OSC stakeholders, which helps developing an innovative model for collaboration in OSC.

2.2 The characteristics of OSC stakeholders

OSC stakeholders are fundamentally different from on-site construction projects largely because of the shift towards factory-based production [37] and "the construction process of OSC is similar to an industrial chain" [38]. Looking at **Figure 1** for better realisation, characteristics of OSC are in between manufacturing industry and in situ construction. On one hand, Yu et al. [39] hold that OSC is fragmented in nature. Ji et al. [13] analysed the stakeholder relationships of OSC in China and realised that the whole network is not dense and less tied. Processes and network relationships in OSC are "non-linear, complex, iterative and interactive" [40]. That is owing to the complexity of the progression of design and the gigantic input from specialist sub-contractors and component producers and suppliers.

On the other hand, Teng et al. [41] developed the symbiosis model and evidenced the effectiveness of symbiotic relationships within the OSC industry chain. On the same stream, Xue et al. [42] investigated the collaborative relationships among innovative organisations in OSC industry. While in US electrical construction prefabrication, Said [43] studied well-built supply chain collaboration and labour union relations then identified improvement opportunities. Those are in line with the notion that standardized goods and services have been enjoined to involve a long-term and loose supplier-buyer partnership, whereas unique deliverables such as buildings demand tight and long-term buyer-provider relationships [44]. Also in course of future research agenda, Goulding et al. [45] emphasised the urgency of novel models of "integrated and seamless team" within OSC sector.

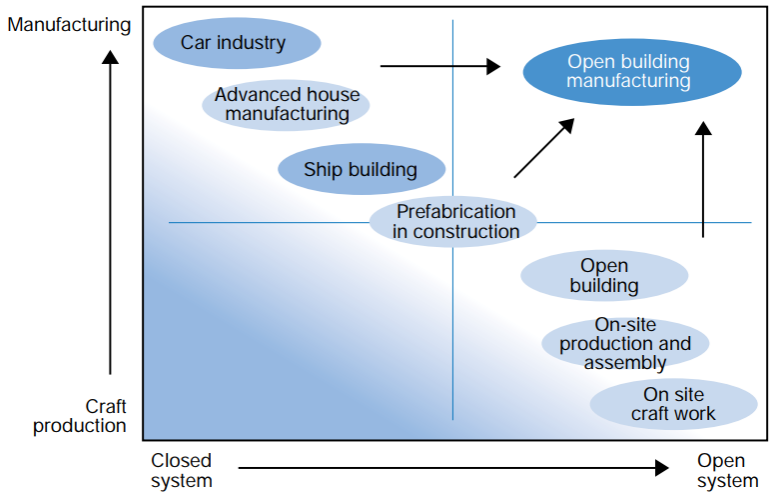

Figure 1. The intermediate position of OSC between manufacture and site-based construction [46]

The OSC supply chain differs from the traditional manufacturing and construction sector supply chain [47]. Figure 2 partly depicts this opinion through an adaptation of Harland's (1996) study. Firstly, both push (make to stock) and pull (just-in-time construction activities) co-prevail in the OSC supply chain. Since which, an OSC supply chain may be more susceptible and complicated than either the sheer manufacture or the onsite traditional construction. Secondly, the component manufacturer plays the pivotal role in OSC due to the low standardisation of component part and fluctuating capacity planning. Thirdly, the collaboration between the participants, therefore, is significantly closer in the OSC supply chain. The entire stakeholders of production, transportation and assembly necessitate well coordinating on real-time basis.

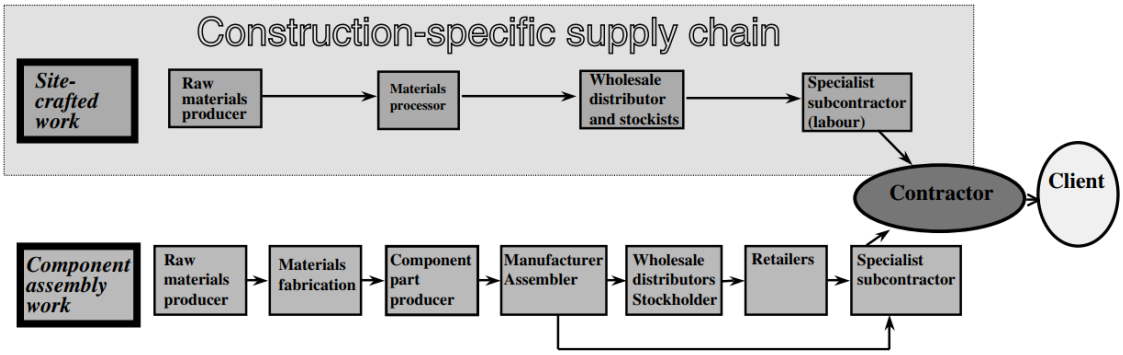

Figure 2. Typical simple construction supply chains by onsite and offsite [48]

Starting in the early 1980s, organisational theorists acknowledged more and more systematically the presence and implications of many organisational outcomes at various levels within the organisation [49]. This multilevel theoretical viewpoint on organisational research with origins in philosophy of general systems represents a shift away from study of organisations through a single lens to organisations as dynamic and interrelated social systems [50, 51]. Within recent OSC literature, and from a broader perspective, Hu et al. [12] proposed a framework based on the interplay between industry, organisation and project levels which will advance understanding of OSC stakeholder concerns.

The module manufacturer or prefabricated component supplier is a distinctiveness as well as a pivot of OSC. The role of the manufacturer becomes increasingly important, since it brings into or eliminates more of the site-based supplies. This special type of supplier gradually incorporate and boost design function so that the more sophisticated building solutions being sold as turnkey packages [52].

3 Social Network Analysis approach to analyse and visualise OSC stakeholders

3.1 Social Network Analysis (SNA) fundamentals

Social network analysis is a strategic approach for examining social structures typically through degree of influence of each actor, the extent of connectedness, cohesiveness and clustering within networks [53-55]. Many scholars believe that the birth of social network analysis stems from Jacob Moreno's [56] illustrative network of social interactions among school children published on the New York Times. During 1960s, SNA was elaborated into a coherent theory and started being adopted across many research fields.

In construction industry, some authors [27, 54, 57] put forward the necessity of integrating SNA and historic project management approaches that consequently marks the synthesis of social science and engineering concepts. SNA is a quantitative tool suitable for construction research [54] which was previously criticized heavily dependent on positivist approaches [58]. Since 2010, SNA in construction industry has dealt with more contemporary topics such as sustainability [59], knowledge management [60, 61], industrial marketing [62], project team communication [63-65]. That trend reinforces the notion that SNA is capable of being used extensively in a wide range of applications and disciplines and in "a variety of levels of analysis from small groups to entire global systems" [66].

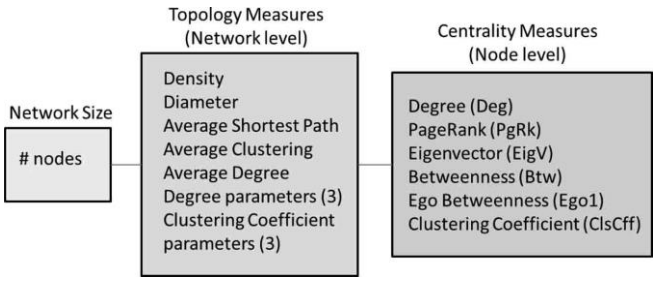

Figure 3. List of variables for the structural analysis of social networks adapted from [67]

Social network analysis characterises networked structures by using nodes (e.g. individuals or groups or organisations or nations) and ties, edges, or links (i.e. relationships or interactions) between them. It also comprises a wide range of measures to analyse networks such as ones shown in **Figure 3**. Multiple literature review studies, for example Yang et al., Mok et al. [25, 28] have addressed the void in terms of multi-stakeholder relationship networks and their dynamics left by the intense concentration on the two-way relational ties between the focal organisation/project team and individual stakeholders. Plus, little attention has been paid to the relationships between stakeholders and their effect on decisions that could influence the performance of the organisation. Given this situation, social network approach seems to be the perfect fit.

3.2 SNA as a holistic approach to analyse and visualise OSC stakeholders

Provided the capabilities to specify the nature of the relationships between stakeholders, viz. actors, and to represent the graphical and numerical properties of the inherent patterns, SNA equips OSC stakeholder for profound and broad insights. **Table 1** summarises how SNA is in sync with OSC stakeholder and its extant research gaps. The levels of analysis along with corresponding SNA variables are included therein.

Table 1. How SNA match OSC stakeholder relationship research

The characteristics of OSC stakeholders	**Some extant research gaps**	**How SNA be the rational approach**	**Levels of analysis and SNA variables**		
			Network level	**Node level**	**Dyad level**
Multi-level interplay	Factors affecting stakeholders' readiness to adopt OSC industrywide [12] Interplay between stakeholder decision making, processes, and outcomes [12]	SNA allows for the selection and representation of an appropriate level of detail that reflects the practical situation where decision-making clusters are processed interdependently and simultaneously by stakeholder groups.	✓ (Centralization; Network Density)		
Non-linear, complex, iterative and interactive relationships	Reversal of OSC stakeholders through out project life cycle [12] Elaborate method to represent OSC processes and relationships	SNA can reflect stakeholder's roles by linking networks to specific project functions. SNA offers a mathematical representation of the differences between systems and projects, as well as the divergences in the positions of actors therein.	✓ (Centralization; Network Density)	✓ (Degree; Betweenness; Closeness; Structural holes)	
Close collaboration	Development of collaborative	SNA enables users to use one systematic	✓ (Centralization;		✓ (Strength of

	procurement in OSC [12] Novel models and configuration of project team [45] Bespoke stakeholder management for OSC projects [12]	format to compare contract terms, information transfer mechanisms and unorthodox frameworks of project management.	Network Density)		tie; Geodesic distance; Structural equavalence)
Module manufacturers as the pivot	Quantifiable importance of manufacturers [12]	SNA enables determination of stakeholders who have strong information flow, brokerage potential, isolated-being, and self-reliance		✓ (Degree; Betweenness; Closeness; Structural holes)	

At the network level, in 1950, Bavelas [68] conducted an influential research demonstrating the significance of the communications network system and its effect on information flow and efficiency. This finding, while preliminary, suggests that the degree to which the network is structured could promote or hinder the flow of information from the stakeholder-orientated stance. The concept of density enables scholars to explain such matters as OSC stakeholders work together or exchange information or could be a group that may support or oppose off-site innovation [69]. At the node level, the position of actors inside the network with regard to others is what OSC researchers have been concerned about. Whereas, The Strength of Weak Tie Theory, posited by Mark Granovetter in 1973 [70], is the most powerful theories at the dyad level. This may help OSC researchers to understand that in considering the information exchange or collaborative dynamics, the strength of ties must be taken into account.

4 The conceptual framework for analysing and representing OSC stakeholders

The proposed conceptual framework aims to synthesise knowledge from various sources and back studies on OSC stakeholders. We conceptualise “what” SNA offer to OSC stakeholder researches (as in **Figure 4**) and exemplary “how” scholars undertake these (as in **Figure 5**).

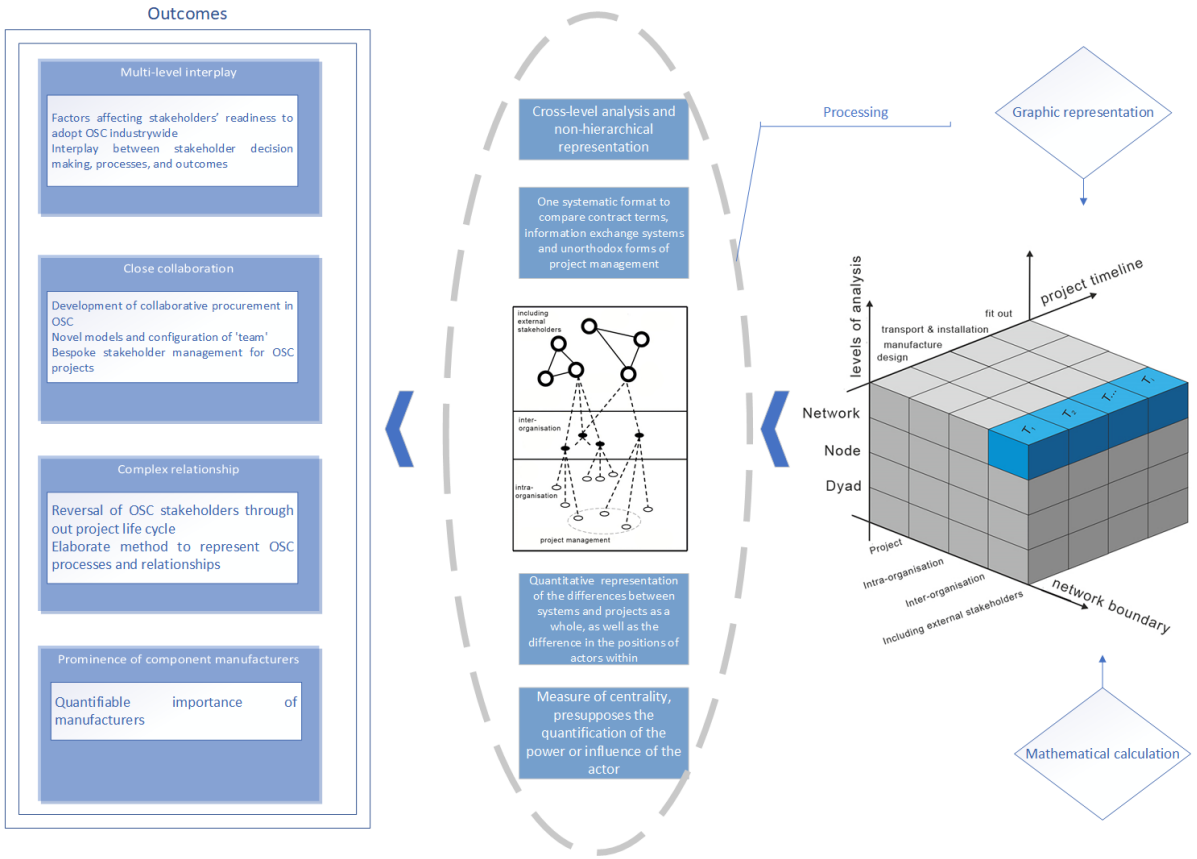

Figure 4. The "What" framework representing fact-finding contents

The *What* framework emphasises twin pillars of SNA which are insightful visualisation and mathematical calculation. Those two pillars support the processing and thereby producing certain outcomes as abovementioned extant research gaps in the realm of OSC stakeholder. Nonetheless, a research should focus on a limited number of outcomes only for avoiding rambling. Notably, the triple dimension of multilayered nature of the network boundary, dynamic features across the OSC project lifecycle and the threefold level of network analysis underlies the cubic as core of theoretical foundation.

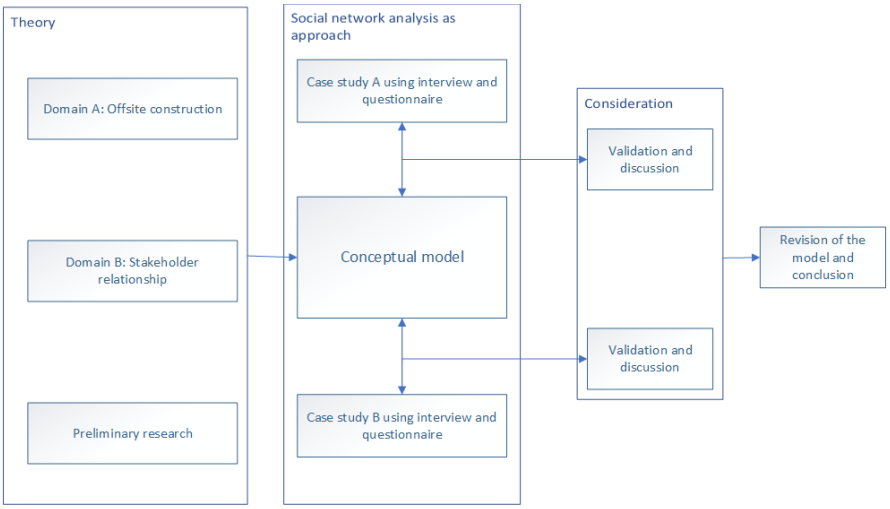

Figure 5. The "How" framework illustrating proposed processing methodology

The *How* framework suggests a procedure for undertaking a research discovering OSC stakeholder relationship patterns using SNA as approach. The conceptualisation is originally adapted from a book of Mills et al. [71] and adjusted to suit SNA theory and techniques. OSC and stakeholder relationship theory and preliminary research together make a sound foundation to build the conceptual model.

5 Discussion and conclusion

This paper draws a picture of OSC stakeholders and SNA potential for deepening the understanding. The framework introduced here is to yield unambiguous concepts of OSC stakeholder research themes and proposed research methodology. Many specialists and scholars hold that extant economic contractual and procurement arrangements are not always effectual for OSC. Policy makers and key industrial players are taking some steps in the right direction by developing adaptive framework agreements. Understanding of ongoing patterns of interrelationship and communication among stakeholders is very likely one of these steps. Whilst previous approaches (e.g. process mapping, linear responsibility chart) are criticised as inefficacious attempts to demonstrate how stakeholders interact and depend on each other, SNA lends a synchronous, consistent and systematised means to the analysis of different contexts. We wish to highlight the importance of SNA for the investigation of OSC stakeholders, and especially encourage the development of the novel collaborative network as a default feature of current available offsite chains. It is our hope that this paper spurs further research in this vein in three future research directions. These are (i) discovery of stakeholder relationship patterns at Australian OSC industry level, (ii) correlations between project/organisational/industrial performance and network topologies, and (iii) bespoke collaborative contractual arrangements and tendering procedures in OSC. SNA provides an analytical and structured approach to align a project management system with functional systems within an industry network. By which, it is realised that some networks are far more effectual than others. OSC professionals and researchers thereupon may take further steps in conceptualising and managing project and supply chain across areas (e.g. contract, team, knowledge, risk) as networks instead of hierarchical or matrix structures. This paper and further research efforts might call for more invaluable insights into social facets of stakeholder relationships in in situ and especially offsite construction.

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